REPORT DOCUMENTATION PAGE	Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
27-01-2013	Conference Proceeding	-

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
A Broadband UHF Antenna on a Non-UniformAperiodic (NUA) EBG Surface	W911NF-12-1-0138
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 611102
6. AUTHORS Nowrin H. Chamok, Mohammod Ali, Steven Weiss	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES	8. PERFORMING ORGANIZATION REPORT NUMBER
University of South Carolina Research Foundatio South Carolina Research Foundation 901 Sumter ST, 5th floor Byrnes Columbia, SC 29208 -0001	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	10. SPONSOR/MONITOR'S ACRONYM(S) ARO 11. SPONSOR/MONITOR'S REPORT NUMBER(S) 61874-EL-II.1

12. DISTRIBUTION AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

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14. ABSTRACT

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15. SUBJECT TERMS

UHF, EBG, Broadband

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Mohammod Ali
UU	UU	UU	UU		19b. TELEPHONE NUMBER 803-777-1488

Standard Form 298 (Rev 8/98)
Prescribed by ANSI Std. Z39.18

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ABSTRACT

A new concept to design thin directional broadband antennas on EBG or HIS surfaces is proposed. Using our proposed concept an octave or more bandwidth is obtained with fairly thin EBG structures even at UHF frequencies allowing low profile antenna design and development. At the heart of the proposed scheme lies the concept of a non-uniform aperiodic EBG surface where the EBG patch size and their inter-element distance are varied according to a specific tapering profile.

Conference Name: IEEE Antennas and Propagation Society International Symposium

Conference Date: July 07, 2013

A Broadband UHF Antenna on a Non-Uniform Aperiodic (NUA) EBG Surface

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Abstract—A new concept to design thin directional broadband antennas on EBG or HIS surfaces is proposed. Using our proposed concept an octave or more bandwidth is obtained with fairly thin EBG structures even at UHF frequencies allowing low profile antenna design and development. At the heart of the proposed scheme lies the concept of a non-uniform aperiodic EBG surface where the EBG patch size and their inter-element distance are varied according to a specific tapering profile.

I. Introduction

Research on antennas integrated with EBG structures dates back more than a decade [1]. Since then there have been many research publications on the subject matter. Hansen's analytical work [2] explained the interaction between a dipole antenna and the reflection phase of an EBG structure. The authors of [3] performed FDTD simulations of the reflection phase and a dipole antenna and obtained a certain range of phase angles that provided a better impedance match for a dipole. Abedin *et al.* [4] introduced the concept of impedance modulation where the impedance of a driven dipole antenna got modulated (not in a communication sense) by the reflection phase of an EBG structure. Azad *et al.* [5] developed a 5.9 mm thick wideband printed dipole antenna on a mushroom EBG structure for operation from 1.75 to 2.5 GHz. This was achieved by optimizing the frequency dependent reflection phase of the EBG structure and then modulating it with the dipole impedance. Other wideband dipole example on EBG includes the work of Akhoondzadeh-Asl *et al.* [6]. Given the advantages of EBG structures in terms of designing and developing thin directional radiating elements it is intuitive that benefits will be more pronounced at the UHF frequency bands. But bandwidth has always been the primary challenge. Although tunable EBG surfaces [7] have been studied by various groups their advantages are limited, e.g. thick, complex because of the need for bias dependent electronic devices. Recently a broadband EBG surface was proposed [8] where several unit cells were repeated in a staggered manner to attain wide bandwidth.

In this paper we take a completely new look into the EBG assisted antenna concept. Instead of focusing on a periodic array of patches of same sizes and periodicity we focus on non-uniform aperiodic EBG structures and explore their potentials for broad bandwidths. First, a uniform mushroom EBG based UHF wideband dipole is designed using our previously proposed concept and design introduced in [5].

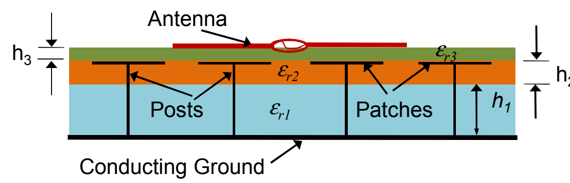
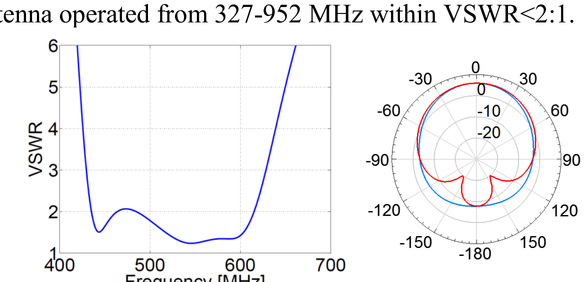


Figure 1. A fat strip dipole antenna on a uniform periodic EBG surface.

Second, a study of an aperiodic EBG structure and its effect on the impedance matching of a fat dipole antenna are studied. We clearly show that antenna bandwidth of close to an octave is possible using this concept with an EBG thickness of 1/30th of the free-space wavelength. It is well known that broader bandwidth can be obtained with thicker EBGs. This paper primarily focuses on how to attain broader bandwidths using thinner EBGs.

II. UHF Uniform Mushroom EBG Surface

Before embarking on the task of studying aperiodic EBG structures we wanted to design a UHF EBG based dipole antenna. A fat dipole with metal strip width =110 mm and strip length=150 mm each was considered. The dipole was excited at the center using a 50Ω gap excitation in HFSS. The total length of the dipole plus the feed gap was 310 mm. The antenna operated from 327-952 MHz within VSWR<2:1.



(a) (b)

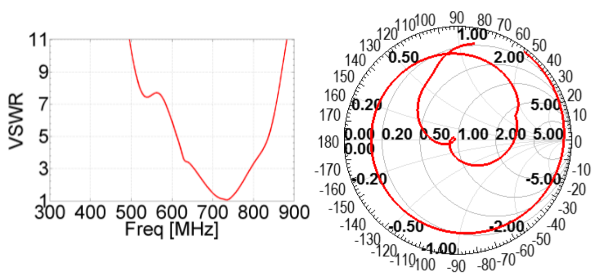
Figure 2. Simulated (a) VSWR Vs frequency and (b) radiation pattern at 500 MHz.

The same dipole was then placed 1 mm above a uniform UHF mushroom EBG surface consisting of 8 by 8 patches each measuring 50 mm by 50 mm. The EBG surface was designed for operation in the vicinity of 500 MHz [5]. The separation distance between the patches was 5 mm. The total length of the EBG surface was 435 mm. Each EBG patch had a 2 mm conducting post connecting it to the ground below (see Fig. 1). The total EBG thickness was 25 mm and both ε_{r1}=ε_{r2}=4.5

(FR4). As apparent from Fig. 2(a) the fat dipole antenna on the EBG operates from 430 MHz to 620 MHz giving a frequency ratio of 1.4 or 40% bandwidth. Antenna radiation patterns (both principal planes) computed at 500 MHz are shown in Fig. 2(b). Patterns are directional with peak gain of 6 dBi and front to back ratio (F/B) of about 18 dB. The same antenna on an EBG consisting of 10 mm thick FR4 and 15 mm thick foam showed about a 50 MHz of frequency shift towards the right.

III. UHF NUA MUSHROOM EBG SURFACE

The total length of the EBG surface was kept constant and then the patch sizes and their inter-element spacings were varied. For example, considering the center patches to be smaller than the 50 mm by 50 mm base cell size a certain percentage of growth in size was considered. A large number of simulations were conducted to study the dependence of the impedance and the VSWR of the dipole antenna in the presence of the EBG surface. The results of one such case are shown in Fig. 3. Clearly starting with a smaller patch size and distance and then gradually growing the patch size and the distance did not yield in a positive outcome.



(a) (b)

Figure 3. Simulated (a) VSWR and (b) impedance data with a beginning patch size of 28 mm by 28 mm.

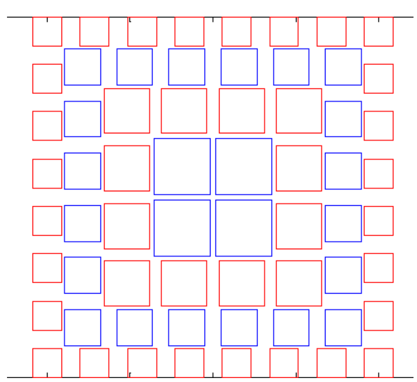


Figure 4. Non-uniform Aperiodic (NUA) EBG surface (top view); vias not shown.

Next, we explored the option of non-uniform aperiodic EBGs where the starting patches were larger while as one moved gradually outward the patches and their inter-element distances were decreased. Considering the same total surface the geometry shown in Fig. 4 was optimized and obtained. Here the starting patch size was 68 mm by 68 mm. This geometry resulted in significant improvement in antenna VSWR (Fig. 5) and gain bandwidths. The dipole lengths were slightly reduced to 120 mm each.

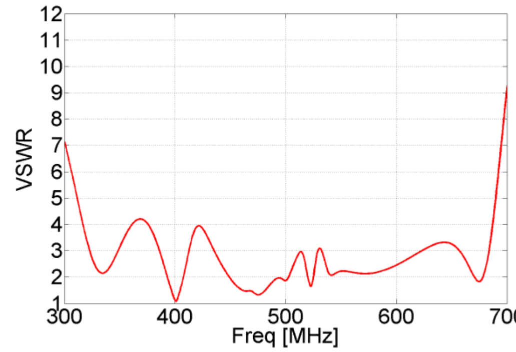


Figure 5. Simulated VSWR of the fat dipole on the non-uniform aperiodic EBG surface.

The VSWR response shows clear potential for broad bandwidth extending from 320-680 MHz within VSWR<3:1 which is more than an octave. Although in some regions across the frequency band the VSWR exceeds 3:1 but it is expected that further tuning will reduce these numbers. The peak realized gain at 450, 550, 600, and 650 MHz are 5.6, 2.8, 5.8, and 4.4 dBi, respectively.

IV. CONCLUSION

A new approach to design and develop broadband directional antennas on EBG surfaces is proposed where a non-uniform aperiodic EBG surface allows signficant improvement in the bandwidth of a thin antenna.

ACKNOWLEDGMENT

This work was supported in part by the US Army Research Office grant W911NF-12-10138.

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